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GEOLOGIC INTERPRETATION OF A RADAR MOSAIC OF YELLOWSTONE NATIONAL PARK*

by

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OF YELLOWSTONE NATIONAL PARK

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Abstract

A radar mosaic of the Yellowstone National Park area depicts the topographic and surface textural features of five major rock units and structural features well enough that a fairly accurate generalized geologic map could be drawn. Correct rock units are shown in 70 percent of the area of this interpretive map. Interpretive errors result in the areas where diagnostic features are masked by surficial deposits or have been modified by glacial scour or young faults.

Introduction

Side-looking K-band radar imagery of the Yellowstone National Park area was flown for NASA by Westinghouse in 1965.[1/] This imagery, which was classified, became available to the U.S. Geological Survey as a series of 10 north-south flight strips at an approximate scale of 1:157,500 in the north-south direction. In 1968, the imagery was declassified and the strips were compiled by the U.S. Geological Survey into an uncontrolled mosaic showing most of the 3,475-square-mile area of Yellowstone National Park at an approximate scale of 1:250,000. The foreshortened east-west direction of the mosaic has an approximate scale of 1:207,500. The illustrations in this report, however, have been reduced to about half the size of the original mosaic. Because some of the flight strips are east-looking and some are west-looking, the resulting mosaic has a variable look direction.

[1/] Imagery was obtained on October 15 and 21, 1965, for the Earth Resources Survey program of the National Aeronautics and Space Administration through the cooperation of the U.S. Army Electronics Command. Photographic copies of the 12 x 18 inch mosaic may be purchased from the Map Information Office, U.S. Geological Survey, Washington, D.C. 20242 at $5.00 per copy.

The original flight strips show many important specific geologic features, but the mosaic better depicts the larger geologic features of the region. The purpose of this report is to point out some of these larger geologic features and to evaluate the usefulness of the radar mosaic as a tool for geologic interpretation.

Side-looking radar imagery primarily depicts topographic forms and surface textures. For this reason, the geologic features which are best shown by the imagery are those having distinctive topographic expression--for example, constructional volcanic forms or young faults. The Yellowstone National Park area is young, both volcanically and tectonically, and therefore is an excellent test area for side-looking radar, despite the fact that much of the terrain is heavily forested.

The radar mosaic of the Yellowstone Park area shows fairly well the generalized distribution of the principal rock types and, to a lesser extent, the major geologic structures.

Delineation of major rock units

From a cursory examination of the mosaic (fig. 1), one can see rugged terrain on the north, east, and southeast sides of the park; this terrain surrounds a central area of more subdued topography. This gross topographic distinction reflects the general geology of the area: a central rhyolite plateau that is surrounded by older rocks. By a more careful study of the topographic forms and surface textures that are depicted on the radar mosaic, at least five subunits that are associated with the major rock types of the area can be recognized. Because the park has been geologically mapped in detail, the specific topographic and textural features that characterize each of these major rock types can be recognized. These five subunits are briefly described and their appearance on radar imagery is shown in figures 2, 3, 4, and 5.

Unit A--"Rugged terrain"

subunit 1 Bold, rounded topographic forms--areas underlain mainly by pre-Cenozoic sedimentary and metamorphic rocks (fig. 2).

subunit 2 Delicately dissected areas--primarily underlain by lower Cenozoic volcanics of the Absaroka volcanic field (fig. 3).

Figure 1.--Uncontrolled radar mosaic of Yellowstone National Park

Figure 2. Radar image of part of Gallatin Range (subunit 1) and Gardners Hole (subunit 5), northwestern Yellowstone National Park.

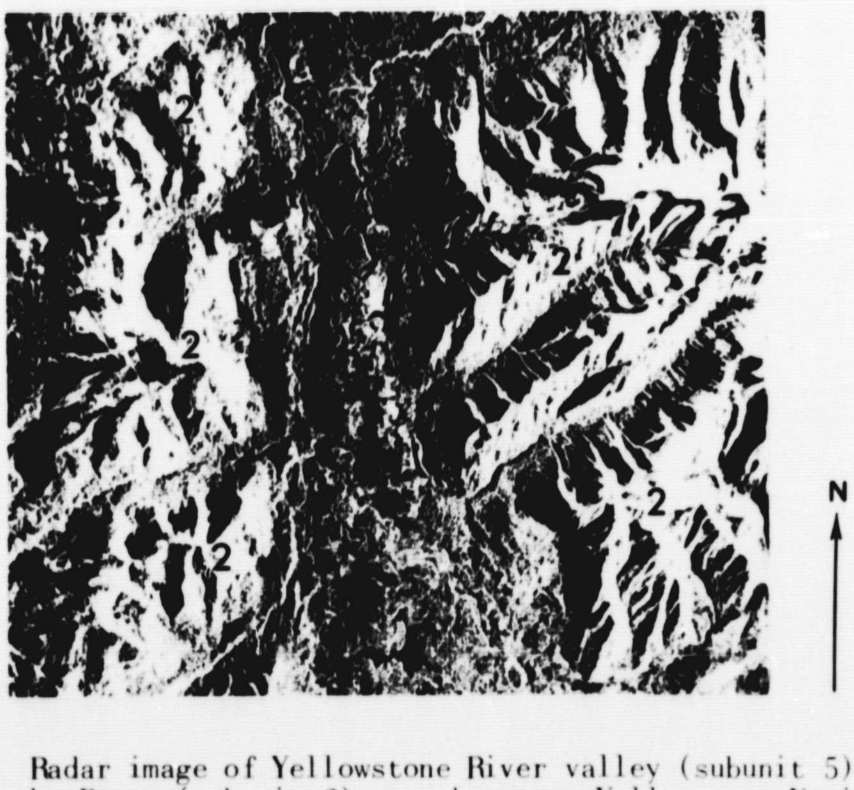

Figure 3. Radar image of Yellowstone River valley (subunit 5) and part of Absaroka Range (subunit 2), southeastern Yellowstone National Park.

Unit B--"Subdued terrain"

subunit 3 Areas characterized by smooth-looking, planar surfaces, which are preserved on drainage divides even where there are numerous canyons --underlain mainly by rhyolite welded tuff (fig. 4).

subunit 4 Areas having a wrinkled surface texture and rounded lobate margins--underlain by rhyolite lava flows (figs. 4, 5).

subunit 5 Areas of thick extensive surficial deposits characterized by a variety of features--broad valleys with meandering streams, meander scars, and terraces; glacial till plains with potholes and drumlinoid ridges; and extremely subdued areas underlain by lake sediments (figs. 2, 3, 5).

Using the diagnostic topographic and textural features of these five subunits, one can now outline their distribution on the radar mosaic in much the same way that one interprets an aerial photograph. Figure 6 shows the interpreted distribution of these five subunits on the radar mosaic; an overlay showing the extent of these subunits constitutes an interpretive geologic map (fig. 7). Note that over most of the Yellowstone Park area specific subunits were identified with confidence. But where the distinction between subunits is not clearcut, the area in question is labeled with a combination of numbers or by the letters A or B. Two examples are: two areas in the southwest corner which are classified only as A or as B without further refinement; and the area labeled 3, 4, north and west of Yellowstone Lake, in which the terrane looked rhyolitic, but the textures were not well enough defined to permit designation as either welded tuff (3) or lava flow (4).

The accuracy of the interpretive map (fig. 7) can be determined by comparing the map with the generalized geologic map (fig. 8). In gross appearance these two maps are similar, but they differ (as expected) in detail. Approximately 70 percent of the area of the interpretive map shows the same subunits as those on the geologic map. The areas of disagreement are plotted on the map in figure 9. The greatest differences are: (a) in the northern part of the park a large irregular area identified as subunit 5 on the interpretive map (fig. 7) is shown on the geologic map to be subunits 1 and 2; and (b) south of Yellowstone Lake the boundaries between units A and B on the two maps are dissimilar.

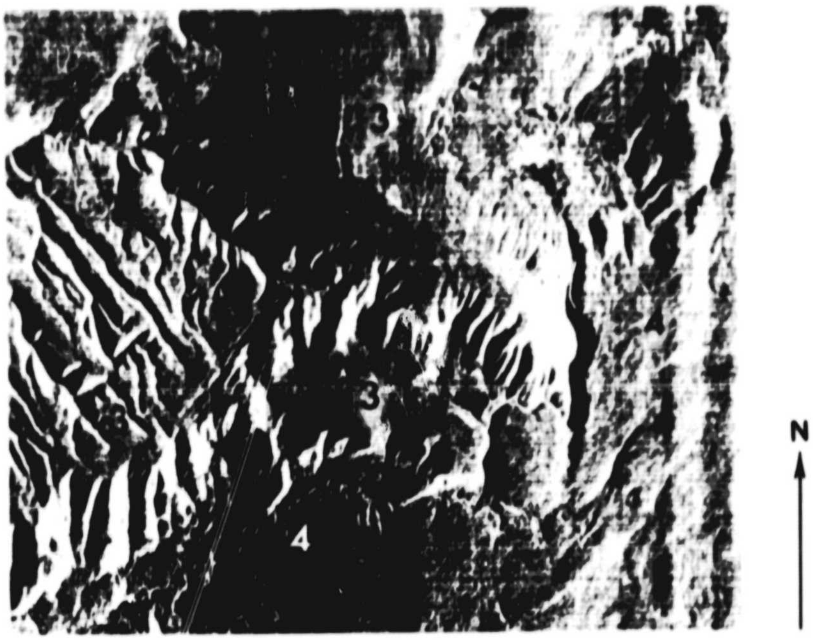

Figure 4. Radar image of Madison Canyon area, west-central Yellowstone National Park, showing Yellowstone Tuff (subunit 3) and rhyolite lava flows (subunit 4).

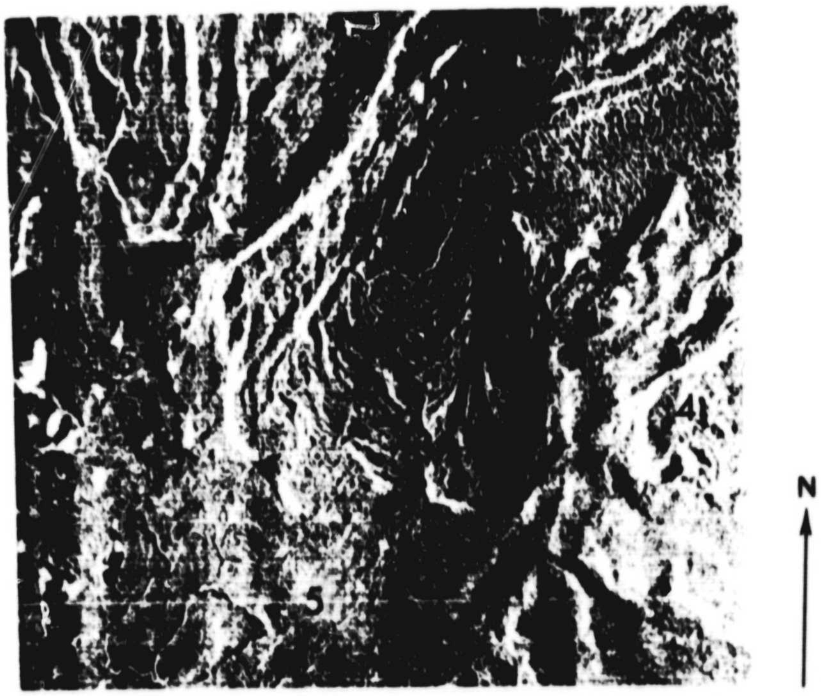

Figure 5. Radar image of southwestern Yellowstone National Park showing Bechler Meadows (subunit 5) and margin of Pitchstone Plateau rhyolite lava flow (subunit 4).

Figure 6.--Uncontrolled radar mosaic of Yellowstone National Park showing distribution of topographic-textural units

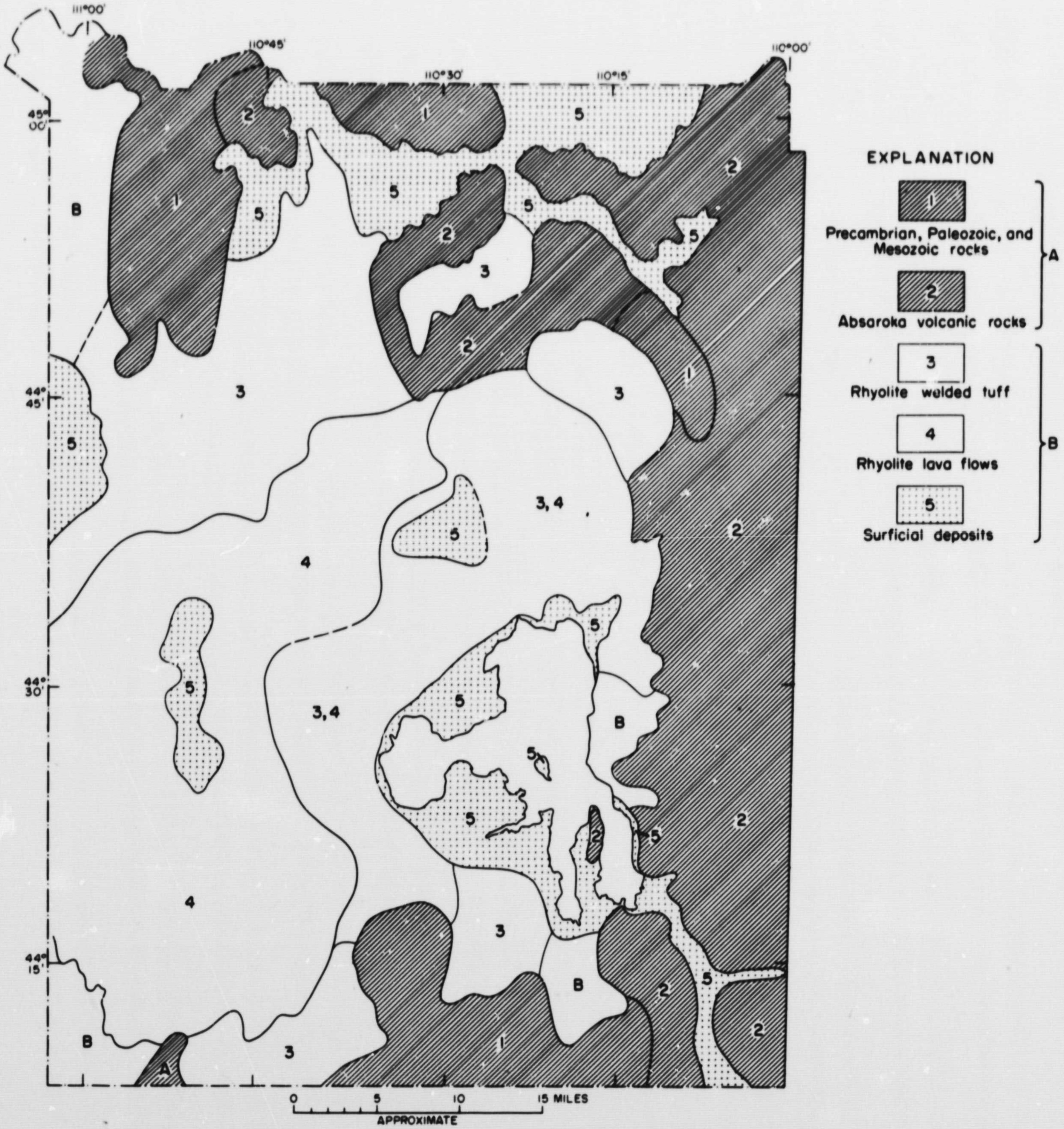

Figure 7.--Interpretive geologic map of Yellowstone National Park

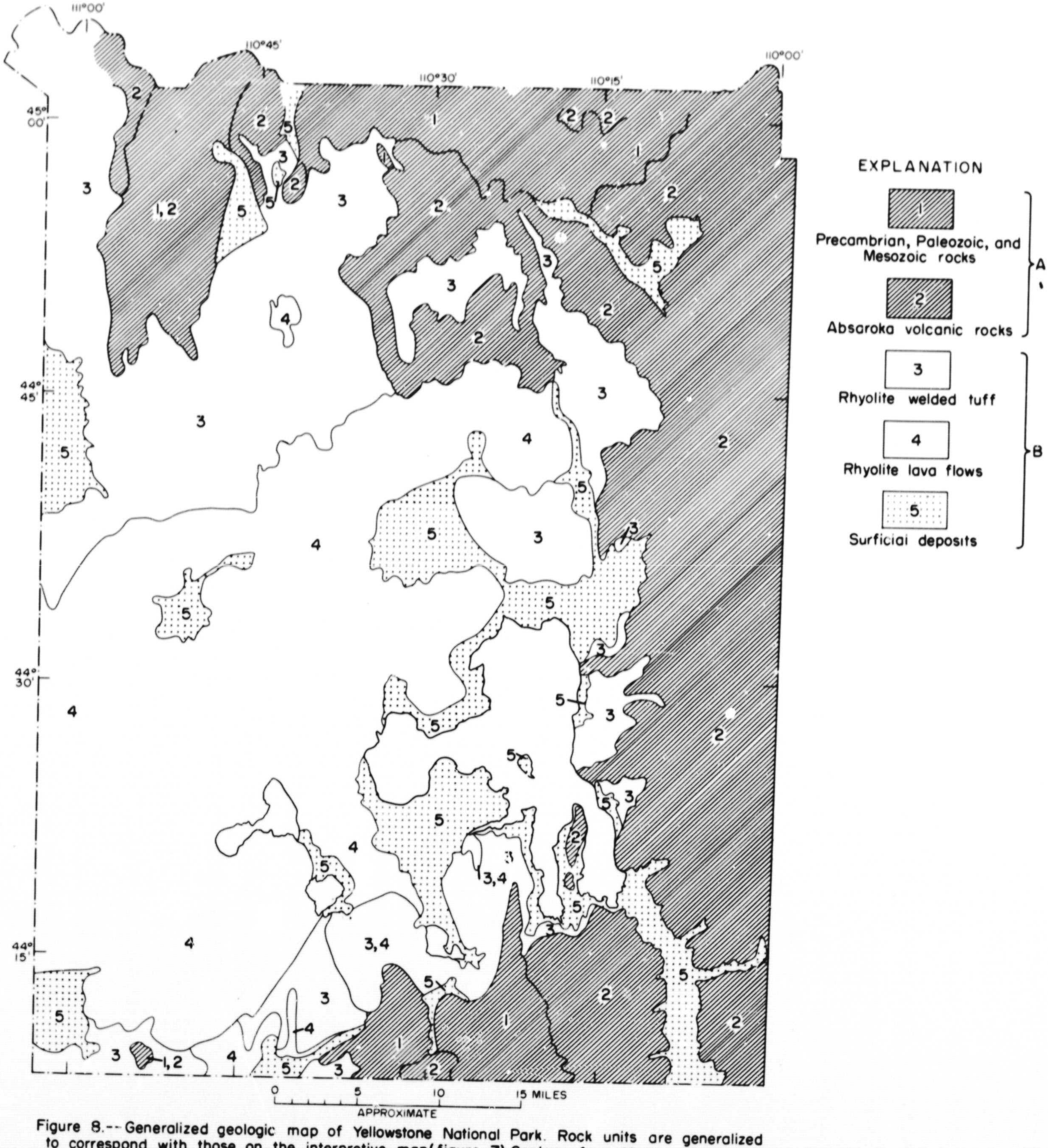

Figure 8.--Generalized geologic map of Yellowstone National Park. Rock units are generalized to correspond with those on the interpretive map (figure 7). Geology from Hague and others (1896), Boyd (1961), and unpublished U.S. Geological Survey data. Contacts transferred by inspection to radar mosaic base using topography as control

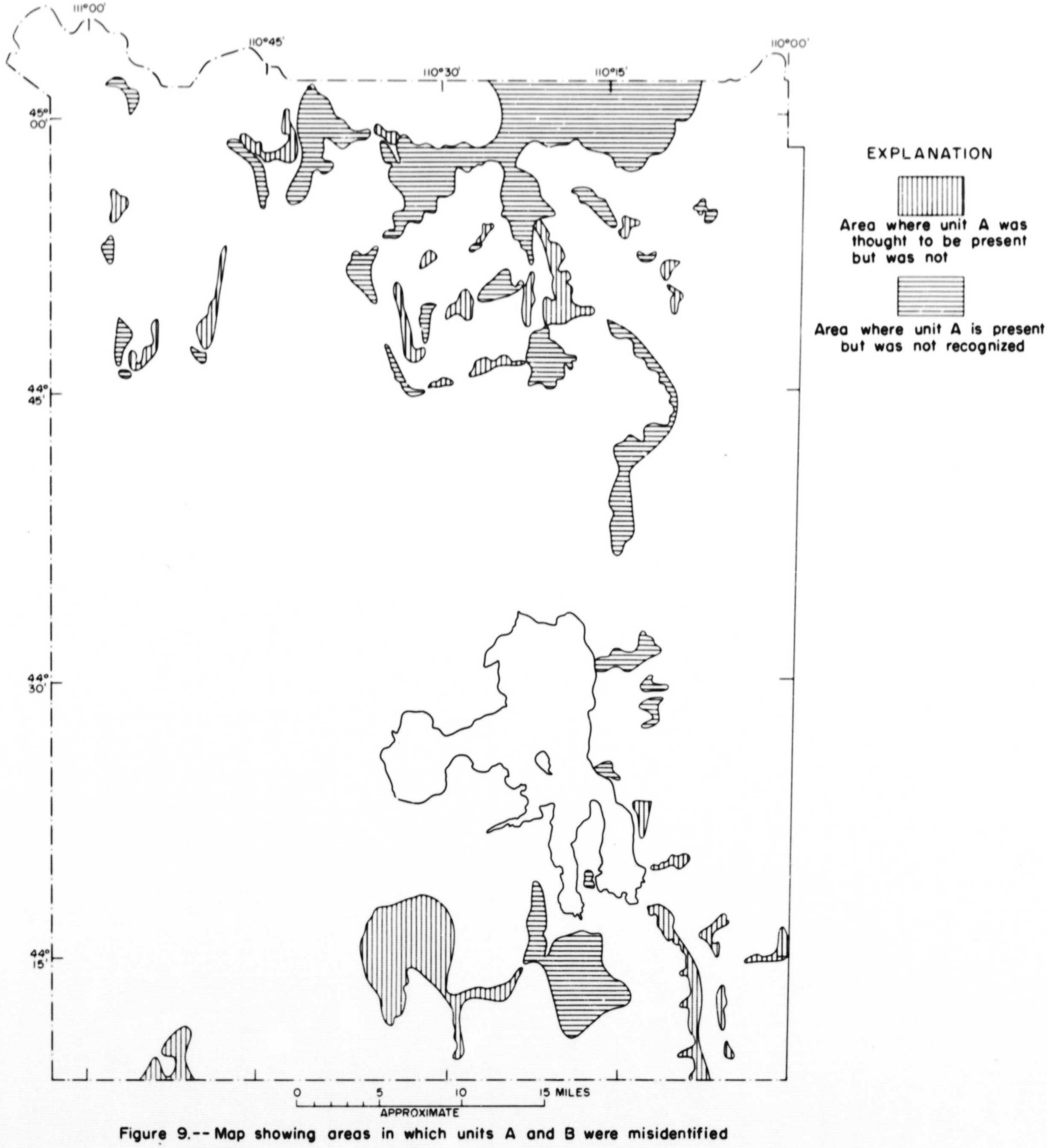

Figure 9.-- Map showing areas in which units A and B were misidentified

There are, however, certain reasons for these discrepancies. The emphasis of the geologic studies in the northern part of the park, for example, was directed chiefly to the mapping of bedrock (subunits 1 and 2) rather than to surficial deposits (subunit 5). Much of this area actually is characterized by pronounced glacial scour and patches of glacial till, and these features were so enhanced by the radar imagery that they seemed to dominate the landscape. Directly south of Yellowstone Lake, the large area misinterpreted as unit B is underlain by fairly nonresistant bedrock (part of subunit 1) which weathers to a subdued topography similar to that which characterizes unit B. Southwest of Yellowstone Lake the discrepancy arises chiefly because of block-faulting, where subunits 3 and 4 have been tilted and eroded to form bold hills and ridges similar to the topography that is more closely associated with subunit 1.

Figure 10 is a map showing those areas in which unit A was correctly interpreted. It was made by superimposing the interpretive map (fig. 7) and the geologic map (fig. 8) and outlining the areas shown as unit A, or as subunits 1 and 2, on <u>both</u> maps. The northeasternmost misidentified area is the area in which Precambrian metamorphic rocks were mistaken for volcanics of the Absaroka field, subunit 2. All the other areas are those in which volcanics of the Absaroka field were mistakenly identified as subunit 1. Significantly, most areas of subunit 2 are underlain by poorly resistant volcaniclastic rocks, which have been delicately incised. But where these volcanics were misidentified and called subunit 1, there are thick sequences of massive lava flows or broad remnants of old erosion surfaces, both of which are features that tend to produce bold topographic forms characteristic of subunit 1.

Figure 11 shows that more than half the area correctly identified as unit B was further correctly subdivided into subunits 3, 4, and 5. Also shown are areas in which this more detailed subdivision was in error and in which detailed subdivision was not attempted. Most of the rhyolitic welded tuff was correctly distinguished from the rhyolite lava flows. The largest area in which it was not possible to make this distinction was around and north of Yellowstone Lake, where very young faults and a rather extensive cover of surficial deposits effectively obscure the diagnostic textural features of the bedrock.

<u>Interpretation of structural features</u>

Unlike the major rock units, the major structural features are <u>not</u> readily interpreted from the mosaic. Some of them can be seen, but others, equally important, are not at all obvious. This is because surficial deposits and jointing, accented by glacial

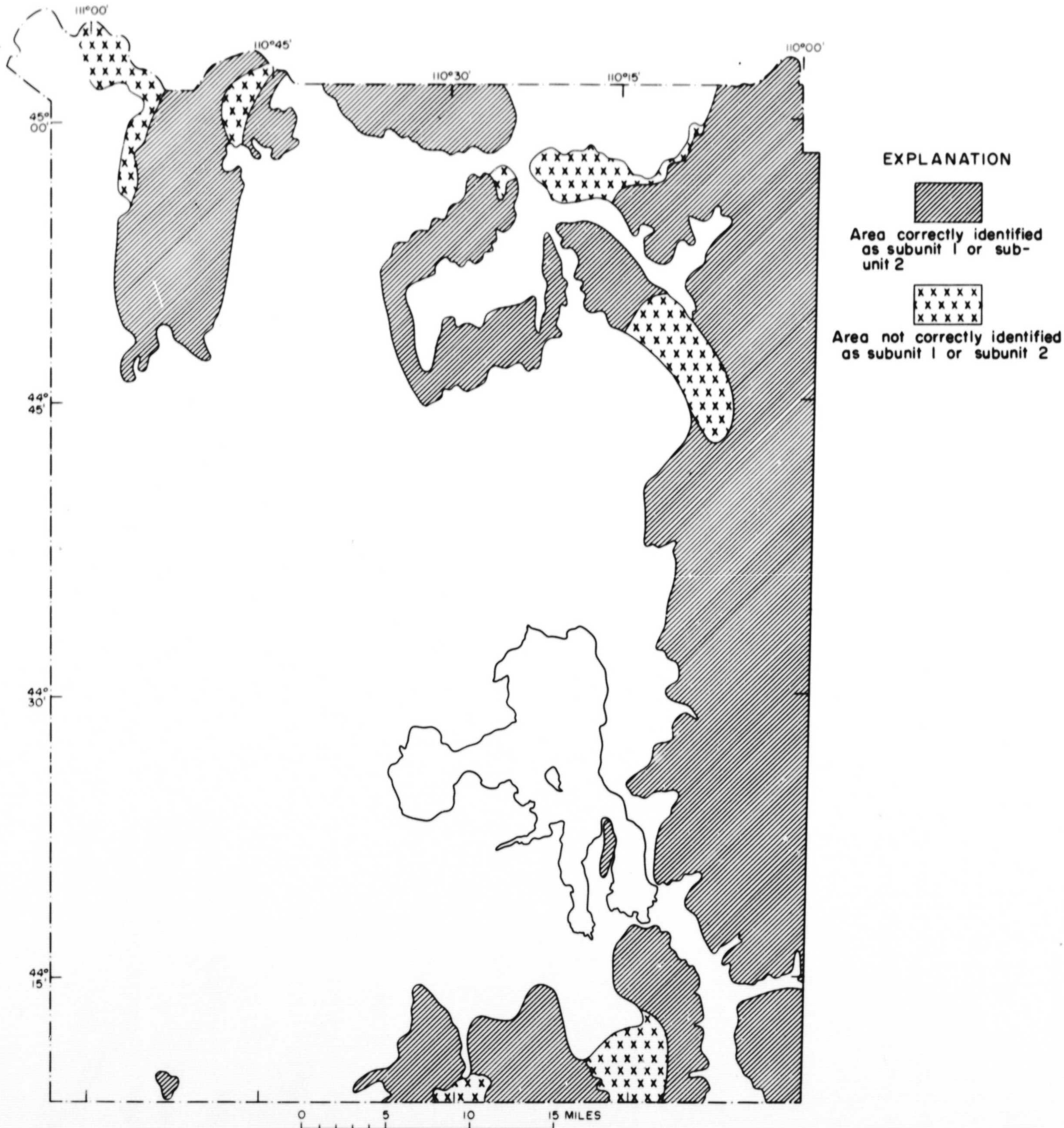

Figure 10.--Map showing areas correctly identified as unit A

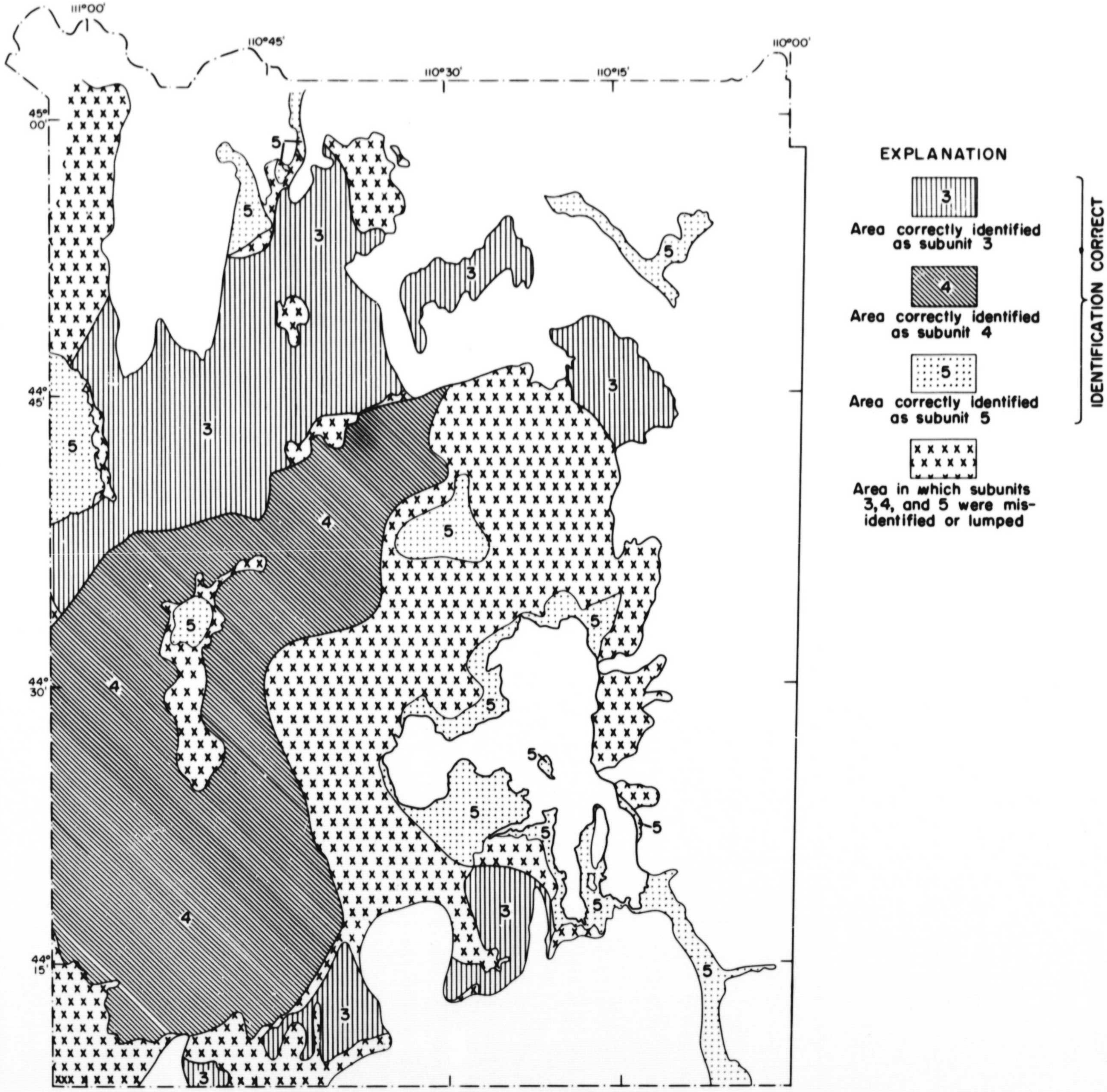

Figure 11.--Map showing areas correctly identified as unit B

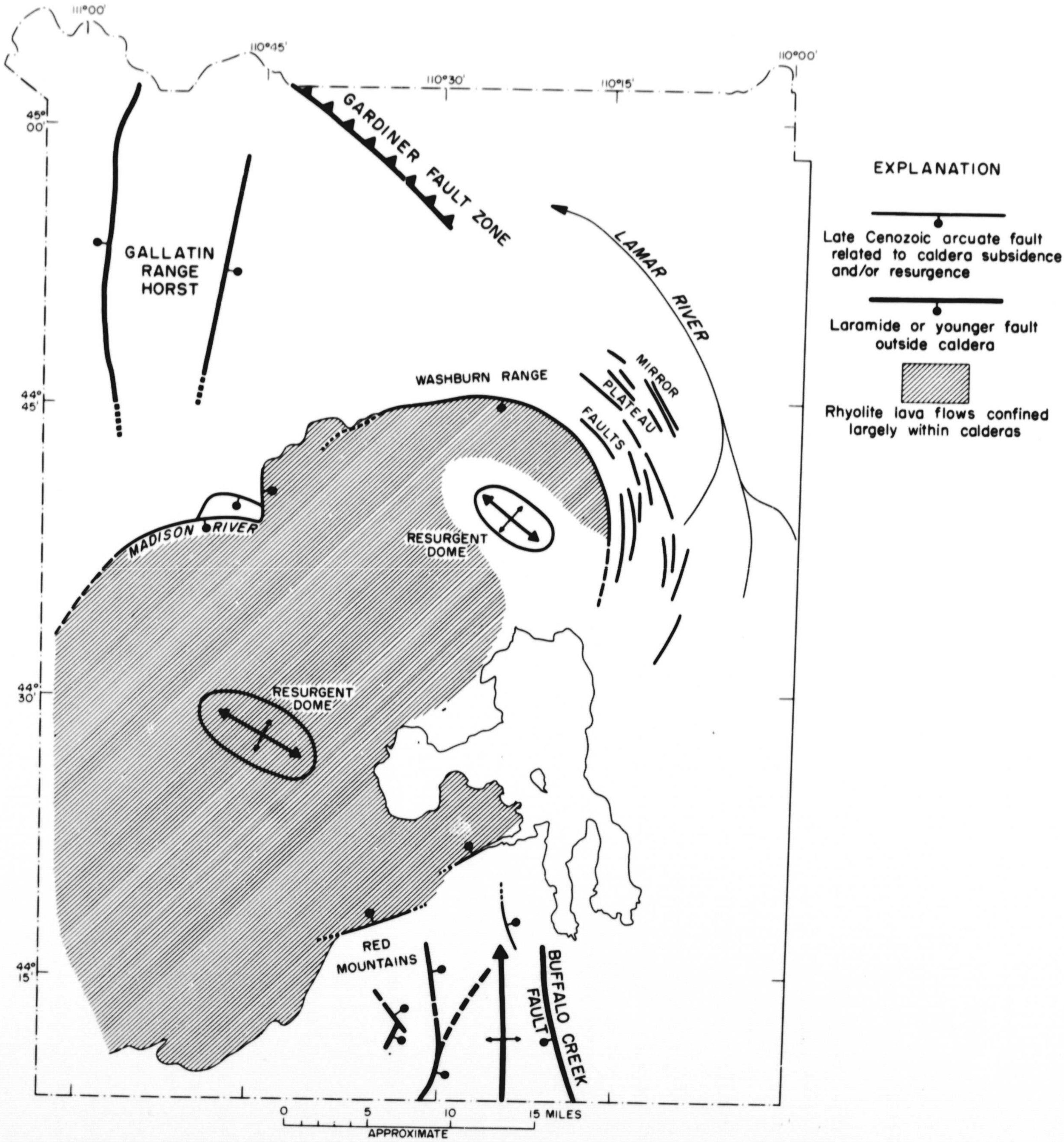

Figure 12.-- Sketch map showing major structural features of Yellowstone National Park

scour, have produced numerous lineaments and small-scale features which mask or detract from the major structural features. Consequently, no attempt was made to directly interpret the structural features from the mosaic. Instead, the major structural features are sketched in figure 12, and the mosaic can be examined for indications of them.

In the northwest corner of the mosaic, the Gallatin Range horst with its bounding faults can be easily seen. The northwest-trending Gardiner fault zone, however, is obscured by a welter of smaller structural features and by a spotty cover of surficial deposits. Similarly, south of Yellowstone Lake, the Buffalo Creek fault is not apparent but there the dominantly north-trending structural grain of the faulted and folded pre-Mesozoic strata in this area is fairly well represented.

The patterned area in figure 12 is dominantly rhyolitic lava flows which are largely contained within two calderas or volcano-tectonic collapse structures. Segments of the curved caldera rim faults are locally preserved and are well shown on the mosaic along the Madison River, the south margin of the Washburn Range, and north of the Red Mountains. Most of these caldera rim faults can be traced to where they disappear beneath rhyolite lavas, which have spilled over the rim and have flowed part way out of the calderas. Numerous faults of Quaternary age on the Mirror Plateau, as well as the course of Lamar River, are concentric to the rim of the northeasternmost caldera and are probably related to collapse or resurgence of the caldera. These faults are easily seen on the mosaic. Two elliptical northwest-trending centers of doming or resurgence near the centers of the calderas can also be seen on the mosaic; the northeastern one is the more obvious.

Summary

(1) Radar imagery is a very useful tool for portraying topographic forms and surface textural features of large areas.

(2) Geology can be successfully interpreted from radar imagery provided that the geological features have distinctive topographic expression. In tectonically or volcanically young areas, such as Yellowstone National Park, radar imagery is especially useful. In older terranes, its usefulness would probably be more limited. Like aerial photography, it can supplement and aid geologic mapping; it cannot, however, replace the man in the field.

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